 doi:10.20944/preprints201810.0743.v1

Attenuated Kinetic and Kinematic Properties During Slow Versus Traditional Velocity Resistance Exercise

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doi:10.20944/preprints201810.0743.v1

ABSTRACT

Purposely slow velocity resistance exercise (i.e., 10 s concentric and eccentric phases) is a popular training method, but limits the loads that can be lifted (e.g., <50% 1 RM). This study compared the biomechanical properties of purposely slow velocity (SLOW) and traditional resistance exercise (TRAD) that uses maximal lifting velocities. Healthy resistance-trained men (n=5) performed two testing sessions (barbell squat and bench press) in random-order; a SLOW session (1 set x 10 repetitions at 28% 1 RM, 10 s concentric & eccentric), and a TRAD session (3 x 10 at 70% 1 RM, controlled eccentric and maximal concentric). A force plate and linear position transducer were used to collect kinetic and kinematic data for every repetition of both protocols ($\alpha = 0.05$). For both exercises, both concentric and eccentric mean force (N) and power (W) for each repetition was greater for TRAD. When the entire training session (squat + bench press) was examined, SLOW exhibited greater time under tension, while TRAD produced greater work (J) and impulse (N·s). Contrary to suggestions in both the lay and scientific literature, purposely slow resistance exercise produced less force, power, and work than traditional velocity resistance exercise.

Key words: force, power, velocity, impulse, weight training

INTRODUCTION

Resistance exercise has been used for many years to enhance health and sport performance. There are a number of ways to vary resistance exercise, including altering exercise selection, order of performing exercises, load being lifted, and velocity of the lift [4]. Of these, altering the velocity of a submaximal resistance exercise by performing the movements very fast or very slow may lead to differing effects. Controlled velocity, or purposely slow resistance exercise, is a form of resistance exercise in which the speed of movement is drastically reduced or controlled to a certain tempo. This is distinctly different from more traditional types of resistance exercise which often encourages movement to be as fast as possible [7]. Over the years, purposely slow velocity resistance exercise has gained some popularity because of the simplicity of the program, the lack of time it purportedly takes to perform each training session, claimed safety considerations, and supposed physiological training benefits [2, 3, 11, 22, 25].

Those who advocate using purposely slow velocity training with sub maximal loads for healthy individuals and for sport performance promote this type of resistance exercise as a way to safely and effectively increase muscle size and increase resting metabolism, thus promoting weight loss [10, 22, 25]. In some cases, this type of resistance exercise may be extremely slow (e.g., as slow as 10 sec eccentric phase and 10 sec concentric phase). Proponents for resistance exercise at this slow of a velocity claim that only 1-2 training session per week need to be performed depending on the size of the muscles [2, 10]. Numerous proposed benefits for purposely slow velocity resistance exercise can be found in the lay literature, including potential improvements in strength, bone density, cardiovascular efficiency, flexibility, resistance to injury, improved blood pressure, as well as decreased body fat [2, 22]. Additional claims include

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physiological changes such as increased muscular endurance for daily functions and enhanced sport performance [2, 10, 22]. Regardless of the exact tempo, few scientific data are available concerning the biomechanical properties of this type of training [12, 21].

Several biomechanical claims for purposely slow velocity resistance exercise have been challenged [21]. For the purposes of this paper, traditional resistance exercise will be defined as training where the resistance is moved either as rapidly as possible or attempts are made to move the resistance quickly (i.e., typically ≤ 1 sec concentric and ≤ 1 sec eccentric phases). Proponents of purposely slow velocity resistance exercise claim the force one produces is increased during purposely slow velocity training because momentum is decreased compared to high velocity exercises [2, 22]. The argument is that during a traditional (fast) exercise, momentum is increased at the beginning of the repetition, supposedly allowing the weight to contribute to the movement and reducing the effort throughout full exercise range of motion [2, 8, 10, 22]. However, it must be noted that Newtonian physics defines force as a product of mass and acceleration, and momentum as a product of mass and velocity, which means increasing force requires increasing momentum [19, 21]. Another supposed benefit of purposely slow velocity resistance exercise is an increase in power due to the purported increase in force [22, 23]. In reality, a reduction in velocity would actually require the force to be extremely high in order to increase the resultant power [19, 21]. During purposely slow velocity resistance exercise, each repetition and each set requires a longer duration to complete. The increased duration of time may increase the perceived difficulty of the exercise, sometimes known as effort. Some refer to this as “the intensity stimulus”, which is related to the degree of effort required [21]. It should be noted, however, that the relative load for resistance exercise is often used to describe an exercise's intensity [5, 6]. For purposely slow velocity training, the load must be decreased as the velocity is decreased. Therefore, slow velocity training is not high intensity training by the generally accepted definitions [5]. It has also been claimed that purposely slow velocity resistance exercise increases the amount of work being performed [2], however there are differing kinds of work, mechanical and metabolic. During purposely slow velocity resistance exercise, the amount of time is increased, but the amount of mechanical work is actually likely to decrease since mechanical work is a product of force produced and the distance moved [14, 19]. During both controlled velocity and traditional resistance exercise, as long as the exercises are the same, the distance moved should be similar, if not equal. However, the forces likely differ between the two protocols due to the lower acceleration during purposely slow resistance exercise [21].

Previous research has demonstrated that, when purposely slow resistance exercise was compared to a traditional lifting protocol, the VO_2, heart rate response, and energy expenditure was comparable or higher for the traditional protocol [10, 13, 17, 24]. In addition, post exercise lactate concentrations were almost two times greater for traditional resistance exercise compared to slow velocity resistance exercise [10]. One study on the endocrine responses to two different controlled velocity protocol reported few differences in the measured hormones [9]. However, it should be noted that both velocities used were relatively slow. Since traditional resistance exercise produces greater energy expenditure than purposely slow velocity resistance exercise, it may be a more beneficial protocol for body mass control [10]. In a different study, purposely slow velocity resistance exercise with untrained women has been shown to improve muscular strength and muscular endurance, but not to a greater extent than traditional strength training

[20]. It has also been reported that slow velocity resistance training resulted in greater strength increases when compared to traditional velocity training, however, different methods of strength testing were used for each group, thus drawing into question the results [23]. Although many of the claimed characteristics of purposely slow velocity resistance exercise seem to disagree with basic biomechanical principles, there are few studies that have directly examined the kinetic characteristics of this type of training [8, 21]. The purpose of the present study was to analyze the kinetic and kinematic properties of purposely slow velocity and traditional velocity resistance exercise training sessions.

MATERIALS AND METHODS

Subjects

Five healthy, currently resistance-trained men, who were familiar with the barbell squat and bench press, served as subjects (X±SD; age=25.8±3.3 yrs, height=1.76±0.07 m, body mass=92.7±18.7 kg). All subjects were tested for 1 repetition maximum (1 RM) for both the barbell bench press (122.0±29.1 kg) and high-bar parallel barbell back squat (165.0±46.0 kg) exercises [15]. All subjects provided informed consent as approved by the University Human Subjects Committee.

Procedures

The present study used a repeated measures randomized cross-over design to compare the biomechanical characteristics of a purposely slow velocity resistance exercise protocol with a traditional resistance exercise protocol. Each subject performed two testing sessions in random-order; a traditional resistance exercise protocol and a purposely slow resistance exercise protocol. Data collection occurred over a three week period, with testing occurring during the same time of day for each session (16:30-19:00 hrs) to avoid possible diurnal changes in strength levels [15]. Subjects were asked to refrain from eating three hours prior to testing and to avoid a strenuous workout 48 hours prior to testing. To increase external validity, both resistance exercise training protocols were selected to replicate commonly performed protocols for both types of resistance exercise.

For each exercise protocol, barbell position was monitored using a ceiling-mounted Uni-Measure linear position transducer (Corvallis, OR) with a wire cable connected to the barbell. Ground reaction forces were determined with a uni-axial force plate (RoughDeck, Rice Lake Weighing Systems, Rice Lake, WI). When performing bench press exercises the force due to the bench was subtracted from the value of the ground reaction force. All data were sampled at 1000 Hz using a 16-bit analog-to-digital convertor and a Biopac data acquisition system (MP150WSW, Biopac Systems, Inc., Santa Barbara, CA). A Chronomix digital electronic timer (NewChron Associates, Walnut Creek, CA) was used as an audio and visual cue to maintain the prescribed lifting tempo for the purposely slow resistance exercise, and to monitor the inter-set and inter-exercise rest intervals.

The slow velocity protocol used 28% of 1 RM loads for the high-bar parallel back squat, followed by the barbell bench press exercise, as suggested from previous controlled velocity studies and pilot work in our laboratory that indicated this intensity was the maximum that could be lifted for 10 repetitions [10, 12, 24]. The slow velocity protocol also used 1 set of 10 repetitions at a 10 sec eccentric, 10 second concentric tempo with no rest between repetitions.

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Rest intervals were 2 min between exercises. This protocol was based on prior studies [8, 10, 12] done as well as recommendations from proponents of super slow training [2, 11, 22]. The traditional resistance exercise protocol consisted of 3 sets of 10 reps at 70% 1 RM loads with 1 min between sets and 2 min between the squat and bench press exercises, as is commonly recommended for resistance training for fitness [1, 4]. For the traditional resistance exercise session, subjects were instructed to perform each repetition at maximum concentric velocity.

Dependent Variables

Position (m), time (s), and force (N) variables were directly measured for both the concentric and eccentric phases for all sets and repetitions for both exercise protocols. The first derivative of position was used to calculate barbell velocity ($m \cdot s^{-1}$), whereas distance moved (m) was determined from position. Additional calculations were used to determine repetition power (W; force x velocity), and total training session mechanical work (J; force x distance) and impulse (N·s; average force across repetition x time). For each subject values for all repetitions were averaged. Finally, the time under tension (s) for the entire training session was the sum of times for all concentric and eccentric phases of all repetitions performed.

Statistical Analyses

Dependent t-tests determined differences between SLOW and TRAD sessions for each of the dependent variables. Significance was set *a priori* (α = .05). Statistical analyses were conducted using IBM SPSS Statistics software v20. Based on anticipated large differences for force and power from previous related research [8], our sample size was adequate and statistical power was 0.95.

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RESULTS

Numerous significant differences were observed between SLOW and TRAD conditions for both the squat (Table 1) and the bench press exercises (Table 2). The slow velocity protocol took significantly more time to complete the exercises compared to traditional velocity resistance exercise for both concentric and eccentric phases (Tables 1 & 2).

Table 1 – Comparison of squat kinetic and kinematic variables between purposely slow velocity and traditional velocity resistance exercise (X ± SD).

Squat Variables	Purposely Slow Velocity	Traditional Velocity	*p*
Eccentric Mean Velocity (m/s)	-0.028 ± 0.085	-0.715 ± 0.069	<0.001*
Concentric Mean Velocity (m/s)	0.091 ± 0.064	0.589 ± 0.098	0.001*
Eccentric Displacement (m)	0.663 ± 0.069	0.680 ± 0.030	0.453
Concentric Displacement (m)	0.662 ± 0.068	0.702 ± 0.032	0.085
Eccentric Mean Force (N)	1406.8 ± 405.2	1942.7 ± 347.3	0.010*
Concentric Mean Force (N)	1409.5 ± 450.2	2030.8 ± 378.4	0.008*
Eccentric Mean Power (W)	-93.5 6 ± 23.8	-1358.9 ± 285.3	<0.001*
Concentric Mean Power (W)	91.9 ± 21.5	1172.8 ± 267.7	0.001*
Eccentric Time (sec)	9.81 ± 0.36	0.96 ± 0.06	<0.001*
Concentric Time (sec)	9.95 ± 0.67	1.23 ± 0.19	<0.001*

*$p < .05$

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Table 2 – Comparison of bench press kinetic and kinematic variables between purposely slow velocity and traditional velocity resistance exercise (X ± SD).

Bench Press Variables	Purposely Slow Velocity	Traditional Velocity	*p*
Eccentric Mean Velocity (m/s)	-0.042±0.010	-0.533±0.086	<0.001*
Concentric Mean Velocity (m/s)	0.040±0.006	0.389±0.075	0.001*
Eccentric Displacement (m)	0.400±0.051	0.393±0.025	0.789
Concentric Displacement (m)	0.400±0.050	0.400±0.036	0.985
Eccentric Mean Force (N)	445.5±194.7	956.6±2880.3	0.046*
Concentric Mean Force (N)	447.5±195.1	1031.2±309.1	0.036*
Eccentric Mean Power (Watts)	-19.1±10.3	-562.0±198.3	0.005*
Concentric Mean Power (Watts)	18.7±10.8	396.8±152.3	0.006*
Eccentric Time (sec)	9.59±0.44	0.79±0.18	<0.001*
Concentric Time (sec)	9.89±0.30	1.32±0.33	<0.001*

* $p < .05$

The eccentric and concentric displacement measures were not significantly different between the two protocols which demonstrates the range of motion (ROM) for the exercises remained the same. The concentric and eccentric mean forces and powers were significantly greater for the TRAD session for both the squat (Table 1) and bench press (Table 2). When comparing the entire session for both protocols (squat and bench press analyzed together), the SLOW session had significantly greater TUT compared to the traditional session (Figure 1).

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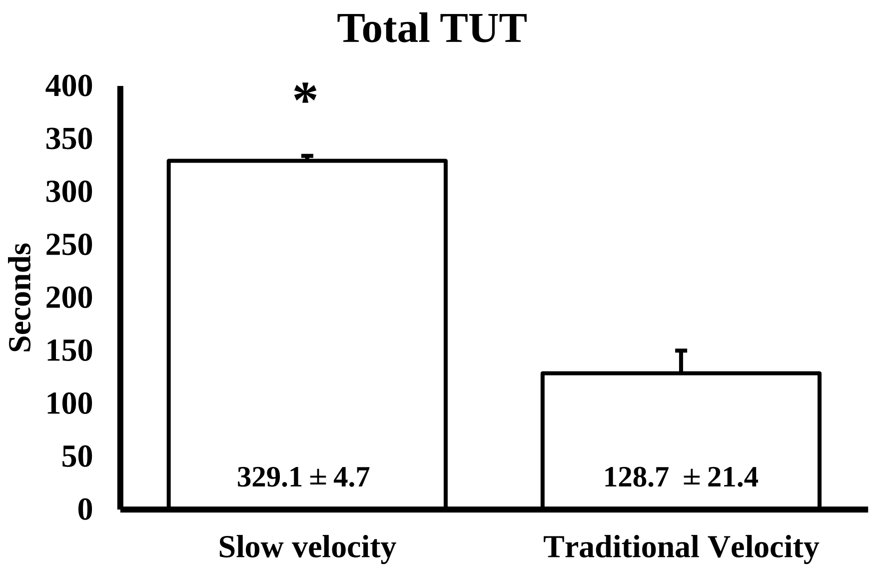
Figure 1 – Comparison of total time under tension (s) for the entire training sessions for both purposely slow and traditional velocity resistance exercise protocols (X ± SD; * p < .05).



Mechanical work was significantly less in the SLOW session in contrast with the TRAD workout (Figure 2). Impulse was also significantly lower during SLOW compared to TRAD (Figure 3).

Figure 2 – Comparison of mechanical work (J) for the entire training sessions for both purposely slow and traditional velocity resistance exercise protocols (X ± SD; * p < .05).

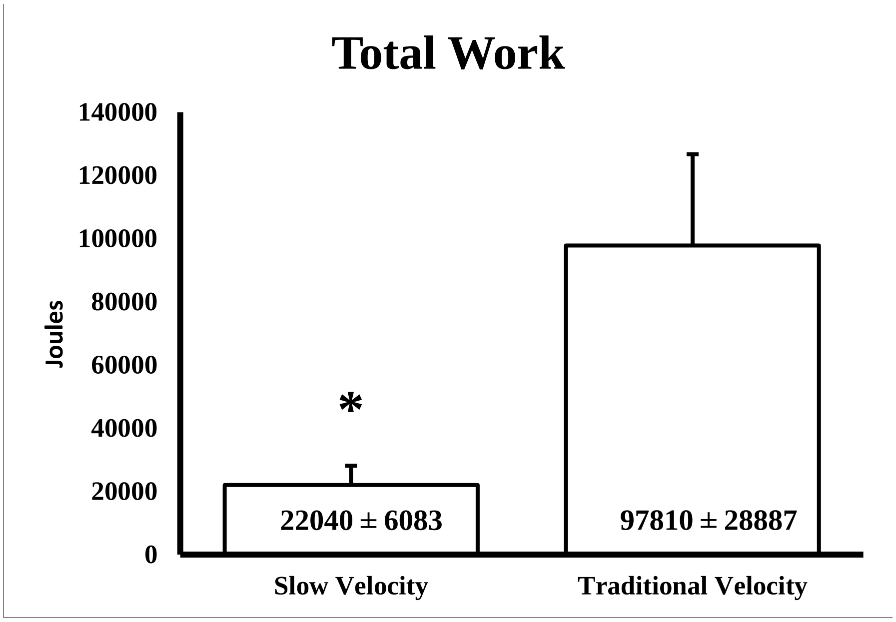


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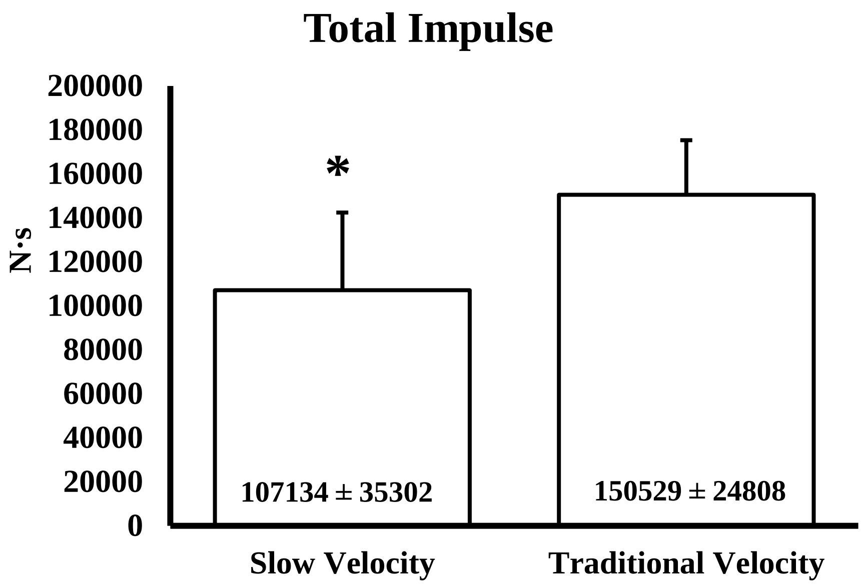
Figure 3 – Comparison of impulse (N·s) for the entire training sessions for both purposely slow and traditional velocity resistance exercise protocols (X ± SD; * p < .05).



DISCUSSION

Kinetic and kinematic properties of the purposely slow velocity resistance exercise protocol was significantly different from the traditional protocol. Visually the exercises are extremely different, but some of the biomechanical arguments used to support the use of purposely slow velocity resistance exercise are not correct. Since momentum is defined as mass times velocity, purposely slow velocity resistance exercise reduces momentum. Additionally, in purposely slow velocity resistance exercise the load is also reduced [19], resulting in lower levels of force [21]. In the present study, the traditional protocol included 3x10 repetitions for the squat followed by 3x10 repetitions for the bench press. The slow velocity protocol included 1x10 repetitions for the squat followed by 1x10 repetitions for the bench press. All the following points of discussion are based on comparing these two commonly prescribed protocols.

Despite the obvious biomechanical differences, claims are still made as to why purposely slow resistance exercise should be preferred over traditional resistance [22]. One is that purposely slow velocity resistance exercise creates longer periods of muscle tension, also known as time under tension. The second is that more muscle force is produced at slow speeds [22]. However, it should be noted that, as shown in the present study, the low relative intensity of the purposely slow resistance exercise produces less muscle force due to the small mass that could be used and the low levels of acceleration purposely produced. The concept that slow velocities produce greater force are based on commonly reported force-velocity curves derived from isokinetic data [21]. The validity of this interpretation of a force-velocity curve requires a maximal effort contraction, not a sub-maximal velocity contraction such as used in purposely slow velocity resistance exercise [21]. The present study clearly demonstrated that, due in part to each repetition lasting longer, the relative intensity was so low that the forces remained low. Another argument used to promote purposely slow velocity resistance exercise is that low velocities reduce the momentum of the load [22]. Although this statement is true, as observed in the present study, it has been clearly demonstrated that greater increases in momentum are necessary for greater levels of force [19, 21]. Since force = mass x acceleration, and momentum = mass x velocity, and the external load being lifted remained constant throughout the exercise, then the only way to increase the force produced is to increase the acceleration (and the velocity), and thus increase the momentum. Another claim for purposely slow velocity resistance exercise is that it produces more muscle power [22]. Power is defined as the product of force x velocity [19, 21]. Therefore, if force is low and velocity is low, the resultant power will also be low. The results from the present study clearly demonstrate significantly lower power production during the slow velocity protocol compared to the traditional protocol.

It has been argued that slow velocity resistance exercise is an effective way to train athletes [2, 3, 10]. It should be noted that many athletic movements require strength, power and speed. A purposely slow resistance exercise training session such as used in the present study requires lifting external loads between 25-50% 1 RM [10, 12, 13, 20, 24]. In cases where high power, strength, and speed is required, as in sports, athletes need to be able to produce high levels of muscle force and power, and high contraction velocities. If purposely slow resistance exercise is the only form of resistance exercise the athlete performs, then they are not training in a manner designed to enhance force, power, or speed [26].

Another reason some have suggested using purposely slow resistance exercise is that it produces less muscle damage while performing the same amount of work [22]. Mechanical work is defined as force x distance [19], and if force is low and distance remains the same as in the present study, the total amount of work will be low. The present study demonstrated the traditional protocol performed significantly more work than the purposely slow velocity protocol. This suggests that although purposely slow resistance exercise is challenging to perform, it results in considerably less mechanical work when compared to traditional resistance exercise. Although never scientifically studied to the authors' knowledge, it stands to reason that if differences exist for muscle tissue disruption between both types of training, it may be due to differing amounts of mechanical work. We acknowledge that our sample size was not large, however, where significant differences were identified the magnitude of dissimilarities was so large that statistical power was adequate. Further research is required to confirm this reasoning.

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CONCLUSION

In conclusion, purposely slow velocity resistance exercise produces less velocity, less force, less mechanical work and less power when compared to traditional resistance exercise. However, total amount of time under tension was greater with the purposely slow velocity resistance exercise compared to the traditional velocity protocol for the entire training sessions. Thoughtful consideration of all factors should be made when designing a resistance training program. Based on training specificity principles, if the primary goal of a resistance exercise training program is to improve muscular force and power, or it is to perform greater amounts of work, than traditional resistance training methods would be preferred.

SUPLEMENTARY MATERIALS

None.

ACKNOWLEDGEMENTS

The authors would like to thank Michael A. Cooper for assisting with the data collection.

 doi:10.20944/preprints201810.0743.v1

AUTHOR CONTRIBUTIONS

Patricia R. Dietz – Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation, Original Draft Preparation

Andrew C. Fry – Conceptualization , Supervision, Methodology, Software, Investigation, Data Curation, Project Administration

Trent J. Herda – Methodology, Software, Data Curation

Dimitrije Cabarkapa – Writing – Review & Editing

Michael T. Lane – Investigation, Data Curation

Mathew J. Andre – Investigation, Data Curation

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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